Received 12 March 2009; revised 11 April 2010; accepted 27 July 2010

Leucorrhinia pectoralis can coexist with fish (Odonata: Libellulidae)

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Key words: Odonata, dragonfly, *Leucorrhinia*, emergence, fish, coexistence, *Carassius*, *Perca*, *Rutilus*, *Tinca*.

Abstract

The Palaearctic libellulid *Leucorrhinia pectoralis* is generally considered to be a species inhabiting fish-free water bodies. Yet, a long-term monitoring study of 38 water bodies in NE Germany resulted in 16 species of fish being recorded in reproductive habitats of *L. pectoralis*, with *Rutilus rutilus* and *Carassius carassius* as the most numerous and widespread fish species. Only 14 water bodies were certainly or probably without fish. The seasonal numbers of exuviae of *L. pectoralis* at the water bodies ranged between 0.1 and 136 per 10 m of bank section. The abundance of *L. pectoralis* was higher in fish-free water bodies (an average of 28.0 exuviae/10 m) than in fish-inhabited waters (1.7 exuviae/10 m). The emergence success of *L. pectoralis* depended on the density and species composition of the fish. If only one non-piscivorous fish species (*Carassius carassius*, *Tinca tinca*) was present at low density, the abundance of exuviae averaged 6.5/10 m. In water bodies containing a multispecies fish fauna that included piscivorous species, combined with high fish density only 0.7 exuviae/10 m were found on average. At localities where the fish fauna was dominated by *Perca fluviatilis* virtually no emergence of *L. pectoralis* occurred.

Introduction

A lot of the habitats of dragonfly larvae are also inhabited by fish. These vertebrates are mostly larger, stronger and faster than dragonfly larvae and may be predators of dragonfly larvae or superior competitors for food. Not surprisingly, the presence or absence of fish has been shown to strongly structure communities of larval damselflies and dragonflies (McPeek 1990; Stoks & McPeek 2003, 2006). Some odonate species are adapted to the presence of fish in the water body. Central European lake species, like *Onychogomphus forcipatus* (Linnaeus), *Epitheca*

bimaculata (Charpentier) and *Leucorrhinia caudalis* (Charpentier), always coexist with fish (Mauersberger & Heinrich 1993; Trockur & Mauersberger 2000; Mauersberger & Petzold 2002; Mikolajewski et al. 2006). These species show a slow lifestyle (Johansson 2000) and are protected by dorsal and lateral spines on the abdomen (Mikolajewski & Johansson 2004) which, in the last two listed species, can be razor-sharp. Actually, this very same defence against fish makes species like *L. caudalis* more vulnerable to large aeshnid predators, thereby excluding them from fish-free habitats (Mikolajewski et al. 2006). Other odonate species prefer fish-free habitats, e.g. *Lestes dryas* Kirby, *L. virens* (Charpentier), *Somatochlora arctica* Zetterstedt and *Leucorrhinia rubicunda* (Linnaeus), but are confronted with the problems of very small water bodies: high temperature amplitude, seasonal drying up and the presence of other competitors and invertebrate predators like Dytiscidae (Jödicke 1997).

The literature on *Leucorrhinia pectoralis* (Charpentier) suggests that it prefers fish-free habitats in Central Europe. Wildermuth (1994) wrote that, in Switzerland, exuviae are to be found only in ponds without fish, and observations of Schiel & Buchwald (1998) in Germany indicate that the larvae are not able to coexist with fish. This is surprising as the species strongly prefers fish lakes in northern Europe (Petrin et al. 2010). Here, I reconsider the larval habitat preference of *L. pectoralis* in Central Europe using a long-term monitoring study of a large set of water bodies in northeastern Germany.

L. pectoralis is a small libellulid species with a distribution from France to Western Siberia (Schorr 1996). It is listed in annex II of the European Habitats Directive.

Study area and methods

The study area is situated at 53°N, 13°E in the glacial lake landscapes of northern Brandenburg and the south of Mecklenburg-Vorpommern, Germany. This region represents one of the core areas of distribution of *Leucorrhinia pectoralis* in Central Europe: the species was found here at ca 120 localities (Mauersberger 2004), and reproduction has been seen at 60 of these within the last 15 years. In this region the species colonised fens and swamps or little shallow lakes with lush submerged and emergent vegetation.

In order to determine the abundance of the dragonfly larvae, I collected exuviae during May and June (1991-2008) in the reed belts of the inhabited waters, often by using a boat. Because of the diversity in size and structure of the water bodies the length of bank section investigated varied from 10 to 200 m. Abundance was recorded as the largest number of exuviae per year per unit length of bank sector; e.g. Behlensee: in 2000 one exuvia was found in a 30 m long test sector (0.33 exu-

viae/10 m). I also gathered information on the stock of fish of the studied localities during the period of exuviae collection.

The habitats of *L. pectoralis* were characterized by high dynamics with respect to the water regime, temperature and oxygen content. They varied from almost drying out to rapidly rising water levels and occasionally oxygen deficiency caused fish mortality. Therefore, only data about fish species composition and fish density from the year of exuviae collection or the year before were used. Some fish data came from published expert studies (Waterstraat & Spiess 1999; Brämick et al. 2002), while some were obtained by electric fishing, by using gill nets, or sometimes by visual observation from the boat at locations with shallow and clear water. Additional information was obtained from local fishermen.

As fish-containing water bodies may differ strongly in their species composition, which may in turn differently affect the densities of odonate larvae, I classified water bodies into five classes based on their fish fauna (Table 1). Figures 1-3 represent characteristic water bodies of types 1, 2 and 5, respectively.

Table 1. Classification of the water bodies containing *Leucorrhinia pectoralis* based on their fish fauna. All of the piscivorous fish also prey on odonate larvae, as probably do most of the non-piscivorous species.

Type	Composition of the fish fauna
1	Free of fish (Fig. 1)
2	Non-piscivorous fish species at low density; typically 1-2 species like *Carassius* and *Tinca*. Water bodies with dense vegetation and regular oxygen deficiency (Fig. 2)
3	Non-piscivorous fish species at medium or high density
4	Multispecific fish fauna including piscivorous fish at low density because of dense submerged vegetation or occasional oxygen deficiency
5	Multispecific fish fauna including piscivorous fish at medium or high density (Fig. 3)
6	Piscivorous fish (usually *Perca*) only or in high dominance

In Table 2 the 38 localities are listed where information about abundance of *L. pectoralis* and fish fauna was available for the same period. If a significant change took place in the fish fauna of a water body over time, the data are listed by year. Each water body was classified into one of the five habitat types given in Table 1.

Figure 1: "Mittlerer Pöhl" — optimum fish-free habitat of *Leucorrhinia pectoralis* with typical vegetation of *Stratiotes aloides* and *Carex rostrata.*

Figure 2: "Moorkolk Warthe" — *Carassius*-dominated habitat of *Leucorrhinia pectoralis*, a small bog lake with blooming *Utricularia vulgaris.*

Figure 3: "Kleiner Törnsee" — unusual emergence site of *Leucorrhinia pectoralis*, a small shallow lake with five species of fish.

Table 2. Average number of recorded exuviae (Abundance) of *Leucorrhinia pectoralis* per 10 m bank section and stock of fish in 38 studied water bodies in the north of Brandenburg and the south of Mecklenburg-Vorpommern (Drewin, Made, Mittlerer Pöhl and Tonloch). Fish species (in taxonomic order) are: *Esox* (*E. lucius*), *Rutilus* (*R. rutilus*), *Scardinius* (*S. erythrophthalmus*), *Leucaspius* (*L. delineatus*), *Alburnus* (*A. alburnus*), *Abramis* (*A. brama*), *Blicca* (*B. bjoerkna*), *Tinca* (*T. tinca*), *Carassius* (*C. carassius*), *gibelio* (*Carassius auratus gibelio*), *Cyprinus* (*C. carpio*), *Silurus* (*S. glanis*), *Anguilla* (*A. anguilla*), *Perca* (*P. fluviatilis*), *Stizostedion* (*S. lucioperca*) and *Pungitius (Pungitius pungitius)*. Type of fish fauna is described in Table 1.

Water body	Year	Abundance	Fish fauna and fish abundance during year of exuviae collection and the preceding year	Type
Lake "Behlensee" SE of Poratz	2000	0.3	*Esox, Tinca,* many *Carassius*	5
Peat digging "Brennbruch" NE of Lychen	2003	1.3	*Carassius* only	3
Carex elata fen at Brüsenwalde	2003	9.0	No fish	1
Riccia pond at Brüsenwalde	2008	72.0	No fish	1
Sphagnum fen at Brüsenwalde	2004	8.0	No fish	1
Lake "Buckowsee" S of Altkünkendorf	2001-2008	0-0.6	*Rutilus, Scardinius, Alburnus, Abramis, Carassius, Perca, Esox, Tinca*	5
Small lake near Chorin, N of Hopfengartensee	2000	0.5	Various species, dominated by *Rutilus*	5
Pond near Drewin SE of Kleiner Drewensee	2003	1.5	*Rutilus*, possibly other species	4
Bog pond "Großer Barschsee" W of Menz	2002	3.6	Probably without fish	1
Lake "Großer Borgsee" W of Meichow	2000-2003	0.0	*Perca* and *Rutilus* abundant, probably other species	6
	2005	0.2	*Perca, Rutilus, Scardinius, Esox, Carassius, Tinca*	5
	2007	1.0	*Rutilus, Scardinius, Carassius, Tinca,* few *Esox*, no *Perca*	4
	2008	7.1	*Rutilus, Scardinius, Carassius, Tinca, Esox,* no *Perca*	4
	2009	0.0	*Rutilus, Scardinius, Carassius, Tinca, Esox*	5
Lake "Großer Törnsee" N of Dollgow	2003	0.2	11 species including *Silurus* and *Stizostedion*	5

Water body	Year	Abundance	Fish fauna and fish abundance during year of exuviae collection and the preceding year	Type
Lake "Haussee" near Neuhaus	1995	1.8	*Esox, Tinca, Scardinius, Carassius*	4
Lake "Heilsee" near Redernswalde	2000	0.5	Many *Rutilus*, some *Esox, Scardinius, Carassius* and *Tinca*	5
Lake "Kespersee" NE of Melzow	1999-2008	0-0.1	A lot of *Tinca, Leucaspius, Scardinius*	3
Kettle hole bog near "Krummer See" E of Melzow	1996, 1997	24.0-32.0	No fish	1
Kettle hole bog SW of Redernswalde	1990	9.0	No fish	1
	1991	35.0	No fish	1
Lake "Kleines Griebchen" SW of Gandenitz	1998	16.3	Probably without fish	1
	2003	0.2	*Carassius* (150 small individuals caught in 2002)	3
Lake "Kleiner Baberowsee" NW of Warthe	2002	1.3	Various species e.g. *Esox, Tinca, Rutilus, Abramis* and *Perca*, medium to high density	5
Lake "Kleiner Törnsee" N of Dollgow	2002	7.0	*Rutilus*, some *Esox, Perca, Abramis*	5
Lake "Krummer See" E of Melzow	2001-2008	0-0.3	*Scardinius, Esox, Tinca, Rutilus, Perca*	5
Lake "Laatzer See" E of Templin	2001	0.8	A lot of *Perca*, some *Carassius*	6
	2002	1.5	A lot of *Perca* and *Carassius*	5
	2003	14.0	Few *Carassius* only (*Perca*-population extinguished in cold winter 2002/2003)	2
	2004	4.0	A lot of *Carassius*	3
	2006-2009	0-2.8	A lot of *Carassius*	3
Lake "Langer See" near Voigtswiese	2000	0.8	*Esox, Tinca, Carassius*	5
Lake "Langes Bruch" N of Wilmersdorf	2002	0.0	A lot of *Carassius* and *Tinca*	3
	2006	0.1	*Esox, Tinca*	5
Pond in lowland of "Lehstsee" E of Lychen	2005	1.7	*Pungitius, Esox*	5
Shallow pool in lowland of "Lehstsee" E of Lychen	2006	8.0	No fish	1

Water body	Year	Abundance	Fish fauna and fish abundance during year of exuviae collection and the preceding year	Type
Lake "Made" E of Mechow	2001	0.6	*Perca, Esox,* many *Rutilus,* some *Blicca* or *Abramis*	5
Peat digging in "Mellenmoor" S of Lychen	1998	29.0	Free of fishes	1
	2001-2002	5.0-8.0	1 small *Carassius* caught	2
Pool "Mittlerer Pöhl/ Keetzseen" S of Neustrelitz	2001	136.0	No fish	1
	2002	80.0	No fish	1
Bog pond "Moorkolk Warthe"	1998	3.8	Probably without fish	1
	2002	3.4	Few *Carassius*	2
	2003	0.7	*Carassius*, lot of juveniles	3
	2004-2006	0.5-1.0	*Carassius*	3
Fen "Moosbruch" near Schreibermühle	2005	6.0	No fish	1
Garden pond in Neuhaus	1998	2.0	Few small *Tinca*	2
	2001	9.0	A lot of *Tinca*	3
	2002	5.0	Few *Tinca, 1 Esox*	5
	2005	0.0	1 *Esox*, 1 large *Tinca*	5
	2007	3.0	No fish	1
Bog lake "Plötzendiebel" N of Glambeck	1991	0.1	*Perca* only	6
	1993, 2008	0.0	*Perca* only	6
Lake "Rohrhahngrund" E of Melzow	1997	0.0	A lot of *Tinca, Rutilus, Carassius* and *Leucaspius*	3
	2001	0.0	A lot of *Perca*, few *Carassius*	6
	2004	0.25	*Perca, Carassius, Tinca, Gibelio, Rutilus*	5
Peat cut "Müllerwiese" near Stechlin	2002	2.5	Probably without fish	1
Lake "Steißsee" S of Metzelthin	2000	4.0	*Rutilus, Esox, Perca, Scardinius, Tinca, Leucaspius, Anguilla*	4
Pond "Suckow-Teich" N of Klaushagen	2001	5.5	Many *Rutilus* and *Scardinius,* few *Esox, Perca, Tinca*	4
Old clay pit "Tonloch" Müritzhof	2004	0.2	Many *Rutilus*, certainly more species	5
Lake "Wildbergsee" E of Melzow	2004	0.3	Many *Tinca* and *Carassius,* few *Gibelio*	3

Results

Only 14 (36.8%) of the breeding habitats of *Leucorrhinia pectoralis* were permanently or temporarily free of fish (Table 2). The others had the following species of fish:

- the piscivorous species *Anguilla anguilla, Esox lucius, Perca fluviatilis, Silurus glanis* and *Stizostedion lucioperca*;
- the non-piscivorous species *Abramis brama, Alburnus alburnus, Blicca bjoerkna, Carassius carassius, C. gibelio, Cyprinus carpio,Leucaspius delineatus, Pungitius pungitius, Rutilus rutilus, Scardinius erythrophthalmus* and *Tinca tinca.*

The fish species that most frequently coexisted with *L. pectoralis* were *R. rutilus* (15 water bodies) and *C. carassius* (14 water bodies). In 17 of the 24 fish-containing water bodies one of these two fish species was the dominant one.

Figure 4 shows the fish-based classification of water bodies (Table 1) with the abundance of *L. pectoralis* exuviae. The abundance of *L. pectoralis* was consider-

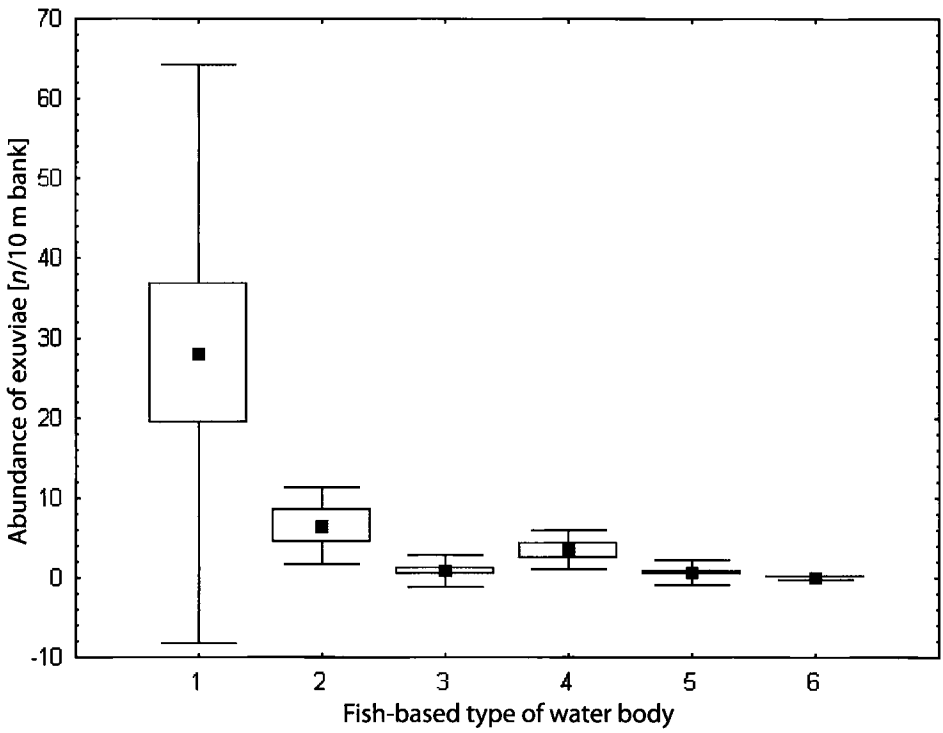

Figure 4: Mean abundance of *Leucorrhinia pectoralis* exuviae (± s.e.; ± s.d.) in relation to the habitat type based on the fish fauna; for habitat classification see Table 1; ⊥ s.d.; □ s.e.; ■ mean.

ably higher in fish-free water bodies (type 1: on average 28 exuviae/10 m) than in fish-inhabited water bodies (types 2-6: on average 1.7 exuviae/10 m). Also within fish-containing water bodies there were strong differences in abundance that were related to the composition of the fish fauna. When only low densities of *Carassius* or *Tinca* were present in a water body (type 2), the abundance of exuviae reached ca 6.5/10 m, while in water bodies with several fish species including piscivorous species (type 5), the average exuviae abundance was only 0.7/10 m. In water bodies dominated by *P. fluviatilis*, *L. pectoralis* was virtually absent (0.14/10 m).

Water bodies with a changing fish fauna throughout the years also showed changes in the abundance of *L. pectoralis* (Table 2). In several water bodies fish disappeared temporarily and this was associated with an increase in the abundance of *L. pectoralis*. In the small shallow lake "Kleines Griebchen" most fish died in the cold winter of 1995/1996. Two years later *L. pectoralis* was present in high numbers. The next stage in the succession was the regrowth of the population of *C. carassius* recorded in 2002. The emergence of *L. pectoralis* then decreased to a very low level in the year 2003. The same temporal pattern was seen in the small peat-cut waters in Mellenmoor near Lychen from 1998 to 2002.

Similarly, the dystrophic bog pond "Moorkolk Warthe"(Fig. 2) was probably free of fish in the first years of investigation (Table 2). In the year 2002 a small population of *Carassius* was noted, but the abundance of *L. pectoralis* did not change. However, in 2003 *Carassius* became very abundant with a lot of specimens with a length of ca 10 cm, and this was associated with strong decrease in the abundance of *L. pectoralis*.

Another case is represented by the small lake "Großer Borgsee", which possessed a species-rich fish fauna dominated by *P. fluviatilis* up to 2005. In the cold winter of 2005/2006 all perches died because of oxygen deficiency during ice covering while the populations of other fish species mostly survived. The abundance of *L. pectoralis* in the years 2004-2006 was very low (0.2 - 0.6 exuviae/10 m) but increased in 2007 (1.2/10 m) and reached quite high levels in 2008 (7.1/10 m). In 2009 I did not find any exuviae of *L. pectoralis* at "Großer Borgsee". *P. fluviatilis* was still lacking, but *E. lucius* was present with a lot of small individuals. But it is worth mentioning that the highest abundance of aeshnid exuviae – *Aeshna isoceles* (O.F. Müller), *Anax imperator* Leach and *A. parthenope* Selys, in total 35/10 m – was recorded in this year (data from 1996-2009).

Discussion

Current data from a large sampling programme across many years and many sites indicate that in the German study area *Leucorrhinia pectoralis* regularly coexists with fish – albeit at lower numbers compared to populations in fishless water bodies. In contrast to many previous descriptive studies I used a more rigorous proce-

dure and only concluded coexistence when the dragonfly larvae and the fish could interact with each other, i.e. when they overlapped in time and space and where the larval habitat was within the reach of fish. In some previous studies *L. pectoralis* was recorded at small fish-inhabited lakes but actual coexistence was not proven. For example, Mauersberger & Heinrich (1993) reported the species from several water bodies (Grosser Briesensee, Jungfernsee, Krugsee, Mehlitzsee and Schulzensee), where fish occurred, but where it was uncertain whether the larval location in the peripheral sedge swamp was also part of the fish habitat. All these and some other doubtful cases have been excluded in the present study. However, it has to be acknowledged that most of the included habitats have submerged vegetation (*Utricularia, Lemna trisulca, Chara, Myriophyllum, Ceratophyllum, Stratiotes,* Figs 1-3), where fish may be inhibited in free movement.

The influence of the fish fauna on the reproductive success of *L. pectoralis* is evident (Fig. 4). The abundance of *L. pectoralis* can be more than 10x higher in fish-free than in fish-inhabited water bodies. Mikolajewski & Johansson (2004) mentioned similar patterns for other *Leucorrhinia* species: *L. dubia* (Vander Linden) having a 7x higher abundance and *L. rubicunda* (Linnaeus) 3x higher abundance in fish-free lakes. Water bodies dominated by *Perca fluviatilis* (Table 2) seem to be very unfavourable – not only for *L. dubia* and *L. rubicunda* (Wittwer el al. 2010) – but also for *L. pectoralis*. This type of water body is inhabited by *L. albifrons* (Burmeister) and *L. caudalis* (Mauersberger 2001; Mikolajewski & Johansson 2004). Probably the strongest proof for fish densities determining *L. pectoralis* densities comes from the strong, coupled temporal patterns in the abundance of *L. pectoralis* and fish in those water bodies with fluctuating fish abundance.

My results show that *L. pectoralis* is able to coexist with fish in a lot of water bodies. Work by Mikolajewski & Johansson (2004) on *L. albifrons* has shown that dorsal spines may defend the larvae against predatory fish. Probably the very pointed, although admittedly rather small, dorsal spines on the abdomen protect *L. pectoralis* against predation by fish such as *Carassius* or *Tinca*, but not against *Perca fluviatilis*. It can be presumed that the decreasing abundance of *L. pectoralis* during a period of increased *Carassius* densities is a result of higher predation, more competition for food, and the impact of the fishes on submerged vegetation, which leads to a loss of oviposition support.

Intriguingly, Wildermuth (1994) and Schiel & Buchwald (1998) concluded that *L. pectoralis* only occurs in fish-free water bodies in Central Europe. Wildermuth (1994) mentioned that, besides *Carassius auratus auratus*, the presence of *Phoxinus phoxinus*, which is able to enter mud and dense vegetation, as the cause for the absence of *L. pectoralis* in peat-cut waters in Switzerland. Potentially, this fish species has the same negative effect on the dragonfly population as *P. fluviatilis* in the current study. In Baden-Württemberg (Schiel & Buchwald 1998) the presence of fish was probably not investigated intensively in the habitats of *L. pectoralis*. Present data, however, indicate that the species does occur, albeit at considerably

lower numbers, in fish-containing water bodies in Central Europe. Interestingly, in northern Europe the species is even a fish-lake specialist, actually preferring and occurring at higher densities in fish lakes (Petrin et al. 2010). Future work should focus on reasons that may explain these geographical differences. It may be important to document differential habitat preferences in order to develop appropriate region-specific conservation measures for this threatened species in Europe.

Acknowledgements

Norbert Bukowsky, Eike Kähler and Henry Wengler gave me advice on ichthyofaunistics. My thanks go also to Jörg Schönfelder and Bernd Trockur who gave me support for Figure 4. The manuscript benefited greatly from helpful comments by Robby Stoks and Hansruedi Wildermuth. Gordon Pritchard polished the language.

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